MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2015/2016

ETM7136 – DIGITAL COMMUNICATION SYSTEMS AND DESIGN

(M.Eng.Tele)

26 SEPTEMBER 2015
9.00 a.m. – 12.00 p.m.
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of **8 printed pages** (including the cover page) with **4 questions only**.

2. **Attempt ALL questions.** All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided. **Show all relevant steps** to obtain maximum marks.

Question 1 (25 marks)

(a) Given a signal $x(t) = 2\prod(3t)$ where $\prod(\cdot)$ is a gate function, find the fourier transform of the following signals:

(i) $x'(t)$ [3 marks]

(ii) $x(t)\cos(6\pi t)$ [3 marks]

(iii) $x'(t)\cos(6\pi t)$ [3 marks]

(b) An analogue telephone line has a signal-to-noise ratio (SNR) of 25 dB and passes audio frequencies over the range of 500 Hz to 4500 Hz. A modem is designed to receive data only over this line without any error.

(i) Evaluate the maximum achieved data rate. [2 marks]

(ii) If the achievable SNR is only 18 dB, calculate the maximum frequency that you can go from 500 Hz to achieve the same data rate in part (i). [2 marks]

(iii) Given a channel with an intended capacity of 50 kbps, determine the minimum SNR (in dB) required to achieve this capacity. [2 marks]

(c) A message signal $m(t)$ is an analogue waveform bandlimited to B = 10 kHz. The spectrum of $m(t)$ is shown in Figure Q1 below.

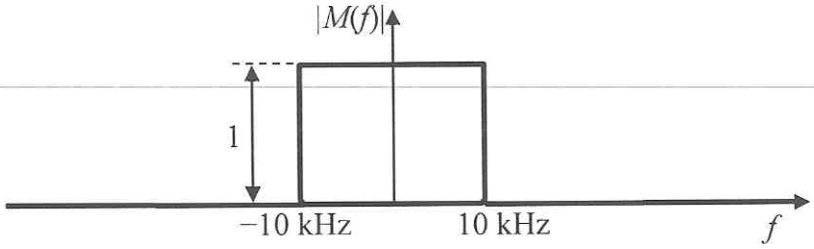

Figure Q1

The waveform is instantaneously sampled at $f_s = 1/T_s = 25\,\text{kHz}$ and passed through a holding network to produce a flat-top sampled signal. The spectral expression of the flat-top sampled signal is

$$M_\delta(f) = \tau f_s \left|\frac{\sin(\pi\tau f)}{\pi\tau f}\right| \sum_{k=-\infty}^{\infty} M(f - kf_s)$$

(i) Is there any aliasing (spectral overlapping) in this flat-top sampling? Briefly explain the reason. [2 marks]

(ii) Given that $\tau = 10\mu s$, sketch the spectrum of the flat-top sampled signal at the output of the holding network. [4 marks]

(iii) Determine the bandwidth of the flat-top sampled signal in (c)(ii). [2 marks]

(iv) What is the main problem associated with the flat-top sampling? Suggest a way to overcome this problem. [2 marks]

Continued...

Question 2 (25 marks)

(a) State one advantage of delta modulation over pulse code modulation (PCM). [2 marks]

(b) The signal $m(t) = 6\sin(2\pi t)$ is digitized using a 4-bit PCM system. The quantizer is of the midrise type, with a step size Δ of 1 V is shown in Figure Q2. Sketch the resulting PCM wave in polar non-return-to-zero (NRZ) line code for one complete cycle of the $m(t)$ input signal. Assume a sampling rate of four samples per second, with samples taken at t = l/8, 3/8, 5/8, 7/8 seconds. [6 marks]

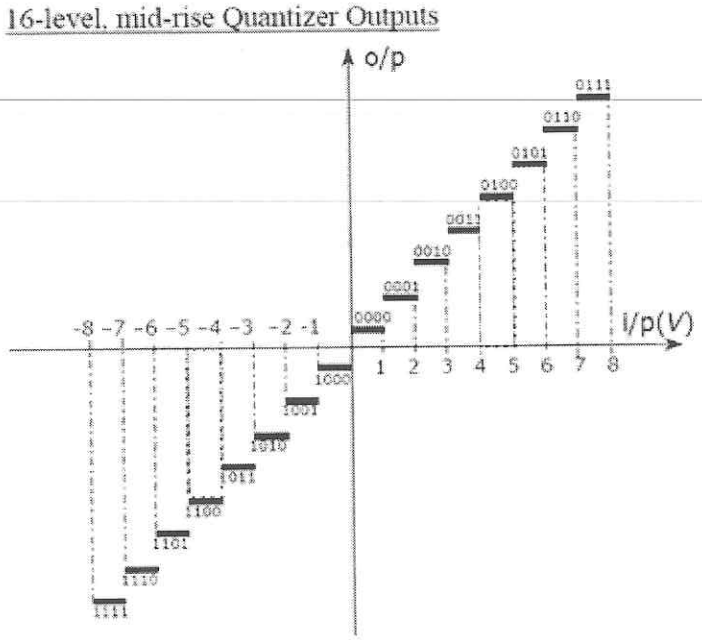

Figure Q2

(c) Consider a signal with spectral components bandlimited to the frequency band 200 Hz to 2200 Hz. The signal is passed through a PCM modulator to obtain a PCM signal. The PCM modulator uses the sampling rate of 6000 samples/second. Assume that the ratio of peak signal power to average quantization noise power at the output PCM modulator is 35 dB (without any bit error).

(i) Determine the minimum number of uniform quantization levels required. [2 marks]

(ii) Determine the minimum number of bits per sample needed. [2 marks]

(iii) Calculate the system bandwidth required for the detection of such a PCM signal. [2 marks]

(iv) What is the main problem associated with the PCM with uniform quantization? Suggest a way to overcome this problem. [3 marks]

Continued...

(d) A PCM modulator is used to digitize an analogue signal which is then transmitted using binary waveforms over a channel that is bandlimited to 200 kHz. The PCM modulator employs a quantizer with 32 quantization levels and the overall equivalent transfer function is of the raised cosine type with roll-off $r = 0.6$.

(i) Determine the maximum bit rate that can be used by this system without introducing intersymbol interference (ISI). [2 marks]

(ii) Compute the maximum bandwidth of the original analog signal that can be accommodated with these parameters. [2 marks]

(e) An 8-ary pulse amplitude modulation (PAM) transmits binary data at the rate of 12 kbps using a raised cosine roll-off filter characteristic. Assume that the system has a frequency response out to 2.4 kHz.

(i) Determine the symbol rate. [2 marks]

(ii) Find the roll-off factor of the filter characteristic. [2 marks]

Continued...

Question 3 (25 marks)

(a) (i) State any two desirable features of digital communication systems. [2 marks]

(ii) Explain with examples, why bandwidth efficiency and power efficiency are two contradictory performance requirements in digital communication systems. [3 marks]

(iii) Is it possible to achieve high bandwidth efficiency and high power efficiency simultaneously using some advanced coding and modulation techniques? Give one example of such techniques if they exist. [2 marks]

(b) For a binary data sequence of [10110001], sketch the bandpass modulated waveform for 4-ASK (Amplitude Shift Keying) and binary-FSK (Frequency Shift Keying) modulation. You can make appropriate assumption on the bit-to-symbol mapping. [5 marks]

(c) Figure Q3 shows two quadrature phase-shift-keying (QPSK) constellations for a $\pi/4$-QPSK modulator. Assume that the modulation starts from scheme (a). Obtain the carrier phase shifts when the input data stream is 10 11 01 00 10 10 10, where the leftmost bits are first applied to the modulator. [3 marks]

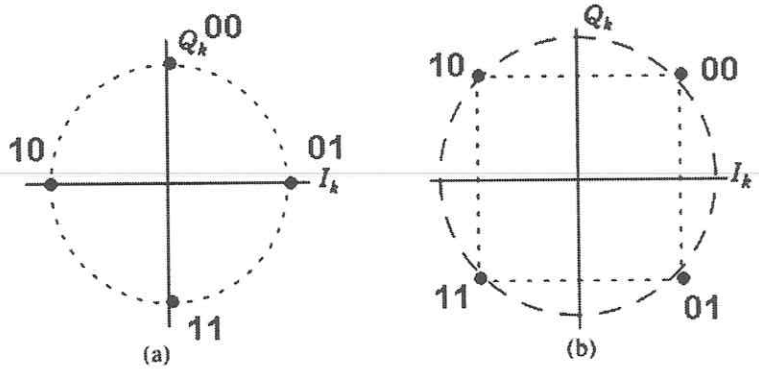

Figure Q3

(d) Sketch the schematic diagram of a maximal ratio combining based Rake receiver used for detecting of direct-sequence code-division multiple-access signals. Briefly explain its working principle. [6 marks]

(e) Frequency-hopping spread-spectrum (FH-SS) signals are used commonly in digital communications systems that require anti-jamming protection. Distinguish the two types of FH-SS signals. [4 marks]

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Question 4 (25 marks)

(a) Orthogonal frequency-division multiplexing (OFDM) is a digital multi-carrier modulation scheme widely used in communication systems.

(i) Give two examples of modern communication systems that use OFDM. [1 mark]

(ii) With the aid of diagrams, describe briefly the basic principle of OFDM and elaborate on how intersymbol interference can be mitigated effectively using this modulation scheme. [5 marks]

(iii) An adaptive version of OFDM called discrete-multitone modulation (DMT) is commonly used in digital subscriber loop (DSL) systems for providing Internet access through the copper telephone lines. Describe two main differences between DMT and wireless OFDM systems. [3 marks]

(b) The Reed-Solomon (RS) codes are the most frequently used block error correction codes in digital applications.

(i) Cite two application examples of RS codes. [1 mark]

(ii) Describe briefly the important features of RS codes. Explain why they are suitable for correcting burst bit errors but relatively sensitive to evenly spaced (bit) errors. [5 marks]

(c) A convolutional encoder can be described by the following generator polynomials:

$$g^{(1)}(D) = D + D^2$$
$$g^{(2)}(D) = 1 + D$$
$$g^{(3)}(D) = 1 + D + D^2$$

(i) The constraint length K and code rate of r of the code. [1 mark]

(ii) Sketch the encoder diagram. [2 marks]

(iii) Sketch the state diagram. [4 marks]

(d) Consider the channel encoder shown in Figure Q4, where the block labelled with 'π' is a data interleaver. [3 marks]

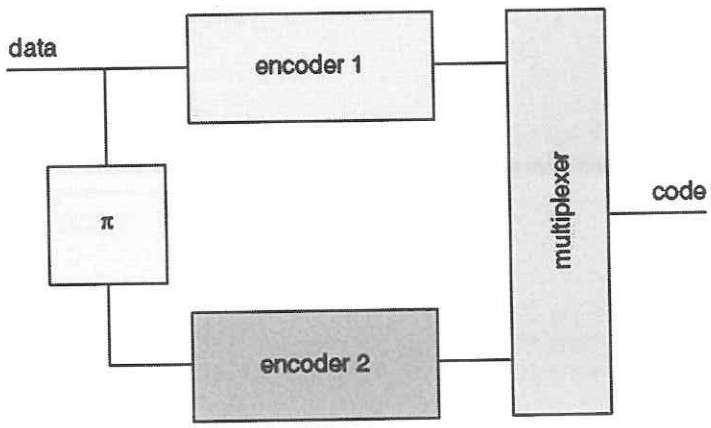

Figure Q4

Name this type of channel code and state its main features.

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Appendix I: Fourier Transform Pairs

Pair Number	$x(t)$	$X(f)$
1.	$\Pi\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc} \tau f$
2.	$2W \operatorname{sinc} 2Wt$	$\Pi\left(\frac{f}{2W}\right)$
3.	$\Lambda\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc}^2 \tau f$
4.	$\exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{\alpha + j2\pi f}$
5.	$t \exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{(\alpha + j2\pi f)^2}$
6.	$\exp(-\alpha\|t\|),\ \alpha > 0$	$\frac{2\alpha}{\alpha^2 + (2\pi f)^2}$
7.	$e^{-\pi(t/\tau)^2}$	$\tau e^{-\pi(f\tau)^2}$
8.	$\delta(t)$	1
9.	1	$\delta(f)$
10.	$\delta(t - t_0)$	$\exp(-j2\pi f t_0)$
11.	$\exp(j2\pi f_0 t)$	$\delta(f - f_0)$
12.	$\cos 2\pi f_0 t$	$\frac{1}{2}\delta(f - f_0) + \frac{1}{2}\delta(f + f_0)$
13.	$\sin 2\pi f_0 t$	$\frac{1}{2j}\delta(f - f_0) - \frac{1}{2j}\delta(f + f_0)$
14.	$u(t)$	$(j2\pi f)^{-1} + \frac{1}{2}\delta(f)$
15.	$\operatorname{sgn} t$	$(j\pi f)^{-1}$
16.	$\frac{1}{\pi t}$	$-j \operatorname{sgn}(f)$
17.	$\hat{x}(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{x(\lambda)}{t - \lambda}\, d\lambda$	$-j \operatorname{sgn}(f) X(f)$
18.	$\sum_{m=-\infty}^{\infty} \delta(t - mT_s)$	$f_s \sum_{m=-\infty}^{\infty} \delta(f - mf_s),$ $f_s = T_s^{-1}$

Continued...

Appendix II: Fourier Transform Properties

Name of Theorem		
1. Superposition (a_1 and a_2 arbitrary constants)	$a_1x_1(t) + a_2x_2(t)$	$a_1X_1(f) + a_2X_2(f)$
2. Time delay	$x(t - t_0)$	$X(f)e^{-j2\pi ft_0}$
3a. Scale change	$x(at)$	$\lvert a\rvert^{-1}X\left(\frac{f}{a}\right)$
b. Time reversal	$x(-t)$	$X(-f) = X*(f)$
4. Duality	$X(t)$	$x(-f)$
5a. Frequency translation	$x(t)e^{j\omega_0 t}$	$X(f - f_0)$
b. Modulation	$x(t)\cos\omega_0 t$	$\frac{1}{2}X(f - f_0) + \frac{1}{2}X(f + f_0)$
6. Differentiation	$\frac{d^n x(t)}{dt^n}$	$(j2\pi f)^n X(f)$
7. Integration	$\int_{-\infty}^{t} x(t')\,dt'$	$(j2\pi f)^{-1}X(f) + \frac{1}{2}X(0)\delta(f)$
8. Convolution	$\int_{-\infty}^{\infty} x_1(t - t')x_2(t')\,dt'$ $= \int_{-\infty}^{\infty} x_1(t')x_2(t - t')\,dt'$	$X_1(f)X_2(f)$
9. Multiplication	$x_1(t)x_2(t)$	$\int_{-\infty}^{\infty} X_1(f - f')X_2(f')\,df'$ $= \int_{-\infty}^{\infty} X_1(f')X_2(f - f')\,df'$

End of Paper